Early Journal Content on JSTOR, Free to Anyone in the World

This article is one of nearly 500,000 scholarly works digitized and made freely available to everyone in the world by JSTOR.

Known as the Early Journal Content, this set of works include research articles, news, letters, and other writings published in more than 200 of the oldest leading academic journals. The works date from the mid-seventeenth to the early twentieth centuries.

We encourage people to read and share the Early Journal Content openly and to tell others that this resource exists. People may post this content online or redistribute in any way for non-commercial purposes.

Read more about Early Journal Content at http://about.jstor.org/participate-jstor/individuals/early-journal-content.

JSTOR is a digital library of academic journals, books, and primary source objects. JSTOR helps people discover, use, and build upon a wide range of content through a powerful research and teaching platform, and preserves this content for future generations. JSTOR is part of ITHAKA, a not-for-profit organization that also includes Ithaka S+R and Portico. For more information about JSTOR, please contact support@jstor.org.

THE PERIODICITY OF ALGAE IN ILLINOIS

By Edgar Nelson Transeau

The following notes on the periodicity of algal occurrence and reproduction are based on a study of collections made at intervals, at more than a hundred stations in East-central Illinois. They cover the period from January, 1908, to January, 1913. About half of these stations are in the vicinity of Charleston. These have been visited at frequent intervals, while those at a distance have been examined at critical times of the year as suggested by conditions at Charleston.

All collections have been preserved in a solution, a liter of which contains 100 cc. formalin, 300 cc. alcohol, and 600 cc. of water. Each collection is labeled and numbered in the field and as soon as convenient a 4 by 6 inch index card is labeled and numbered to correspond. On this is kept (1) a record of the weather conditions, water conditions, temperatures, relative abundance of algae in general, and whether floating or attached, etc.; (2) an analysis of the collection made in the laboratory, showing all algae present as far as identifiable. In the case of many only the genus can be given, together with measurements that might aid in determining them from later collections containing the same forms in a fruiting condition. In summarizing the work it is possible then to go back to cards or to the collections at any time and correct any errors or get any further data desired.

The waters of Eastern Illinois are rich in dissolved mineral matters derived from the prairie soils. For example, the water of the Embarras river near Charleston contains on the average .14042g. of soluble matter per liter. It is consequently not surprising that the algal flora should be large and varied. Its extent may be roughly indicated by the fact that the collections contain more than forty-five species of *Oedogonium,* and the genus *Spirogyra* is represented by at least thirty-five species and varieties. These numbers are considerably more than have been reported from Massachusetts whose algae are better known probably than those of any state in the Union.

In order to get at the periodicity the card records have been listed by months for the five-year period. An examination of the resulting chart shows that on the basis of *their periods of greatest abundance, the duration of their vegetative cycles, and the times of their reproduction,* the algae may be divided into seven classes.

I. Winter Annuals. These are species which begin their vegetative cycle in the autumn, increase up to the time the ponds are frozen, and last over the winter under the ice. During protracted winter thaws—which usually occur in January—they may develop further and even fruit. Their period culminates in March and April. Sexual reproduction may occur at any time from November to April. Zoöspores are formed from the beginning through the period of increase. Aplanospores and akinetes develop mostly during the period of decline (Fig. 1). Some local examples of algae belonging to this type are *Vaucheria geminata, Vaucheria sessilis, Draparnaldia plumosa, Tetraspora lubrica,* and *Stigeoclonium lubricum varians.*

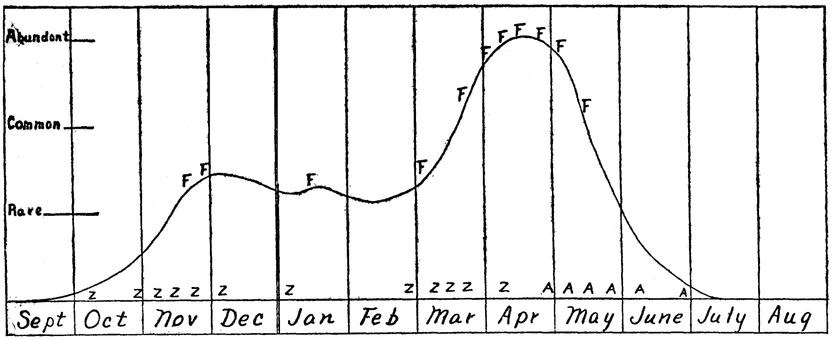


Fig. 1. Frequency curve of winter annuals. In this and subsequent figures the probable occurrence of sexual reproduction is indicated by F, zoospore reproduction by Z, and the formation of aplanospores or akinetes by A.

II. Spring Annuals. These are forms in which the vegetative period begins in late autumn or early spring, culminates in May and declines in June. Sexual reproduction occurs in April, May, and June. Zoöspores are formed mostly in early spring, and aplanospores and akinetes during the period of maximum abundance and decline (Fig. 2). This type includes the largest number of species, among which are *Spirogyra varians, Spirogyra Weberi, Zygnema stellinum, Oedogonium rufescens,* and *Ulothrix variabilis.*

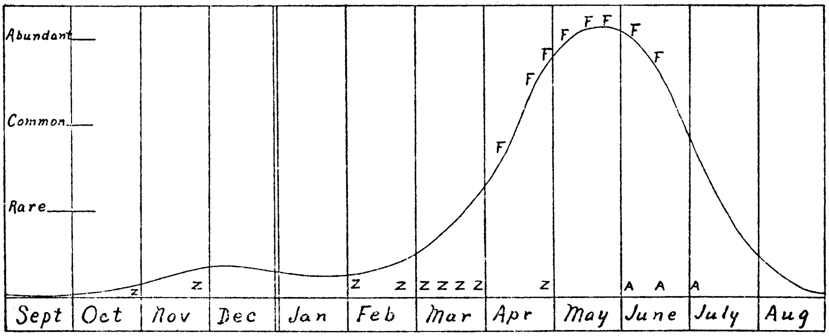


Fig. 2. Frequency curve of Spring Annuals

III. Summer Annuals. The vegetative period of the algae of this class begins in early spring and culminates in July and August. The decline is gradual and extends through the autumn months. Sexual reproduction occurs in July, August and September. Zoöspores, when formed, are most abundant in Spring and early Summer. Aplanospores develop mostly in August and September (Fig. 3). Among the local examples of this class are *Spirogyra decimina, Spirogyra maxima, Schizomeris Leibleinii, Calothrix stagnalis,* and *Oedogonium Vaucherii.*

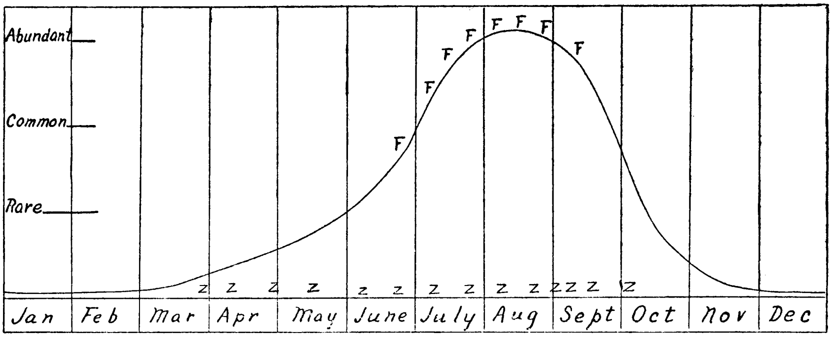


Fig. 3. Frequency curve of Summer Annuals

IV. Autumn Annuals. These species begin their vegetative development in late spring, increase through the summer and have their period of maximum abundance in the autumn. They may disappear at the time of freezing up of the ponds, or gradually through the winter. It has been noticed in at least one instance, *Spirogyra setiformis,* that when the freezing occured at the time of fruiting, a large part of the filaments still in a vegetative condition remained over the winter and completed the fruiting in the early spring. This is indicated in Fig. 4 by the dotted line. The sexual reproduction usually occurs during September, October, and November. Among the algae of this class are *Spirogyra nitida, Rivularia natans, Oedogonium crassum amplum, Spirogyra setiformis,* and *Oedogonium obtruncatum.*

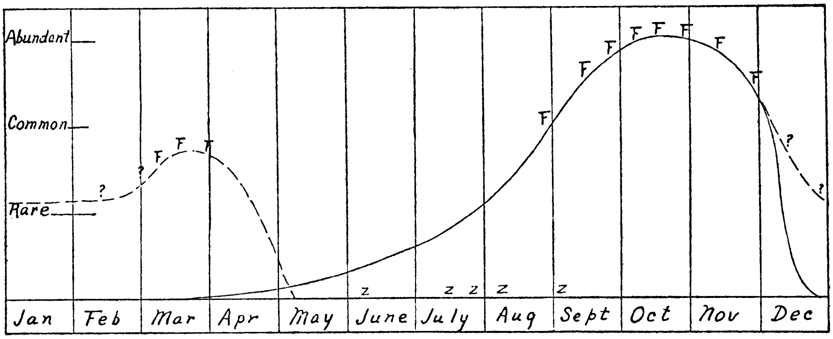


Fig. 4. Frequency curve of Autumn Annuals

V. Perennials. This group includes forms in which the vegetative cycle goes on from year to year without interruption. The algae may become very scarce during unfavorable periods but they are capable of at least maintaining themselves without the production of reproductive bodies. They commonly attain their greatest development during the summer and early autumn. Sexual organs are mostly produced in late spring or early autumn—sometimes in both. Zoöspores are most abundant in spring and summer,—not infrequently they are also produced in autumn (Fig. 5). *Cladophora glomerata, Rhizoclonium hieroglyphicum, Pithophora oedogonia, Pleurococcus vulgaris,* and *Oedogonium grande* belong to this class.

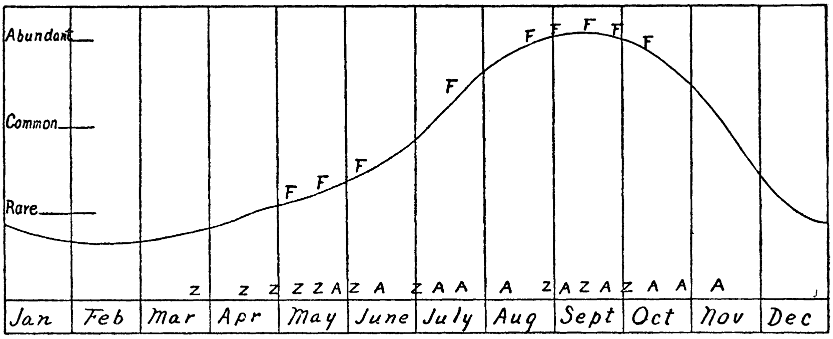


Fig. 5. Frequency curve of Perennials

VI. Ephemerals. These species have very short vegetative cycles, usually best reckoned in days—at most in weeks. Generations succeed one another rapidly through the periods of favorable conditions. Also because of varying capacities to respond to environmental conditions the generations overlap. It is therefore difficult to represent this group by a curve or collection of curves. Figure 6 is an attempt to represent it in general. It must be remembered that the lengths of the curve for a generation will vary in the different species and under different conditions of temperature, moisture and illumination. The species are mostly soil-surface and plankton forms. Few of them reproduce sexually. Zoöspores, aplanospores and akinetes are the usual means of increase, dissemination and passing an unfavorable period. The soil

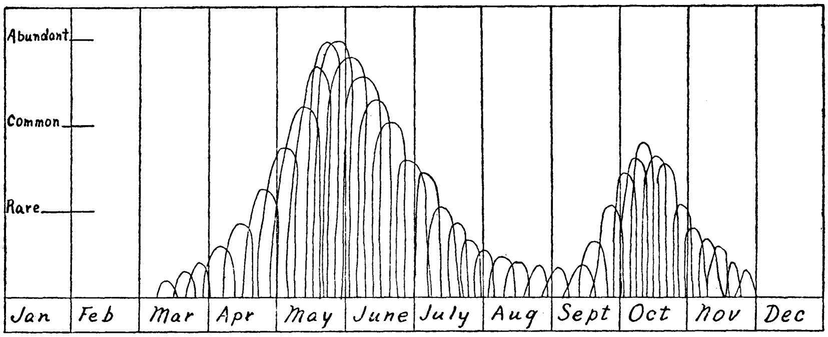


Fig. 6. Frequency curves of Ephemerals

forms are favored by wet weather. All the forms may be found in greater or less abundance in all but the winter months. Among the commoner local Ephemerals are *Botrydium Walrothii, Scenedesmus quadricauda, Pediastrum Boryanum, Vaucheria terrestris,* and *Ineffigiata neglecta.*

VII. IRREGULARS. In addition to the above six types of periodicity there is a group of forms for which the combinations of environmental conditions necessary to induce marked vegetative development or bring about reproduction do not occur with seasonal regularity. The period between maxima may be of more or less than a year's duration. Because of their uncertainty it is difficult to discover them in a five year collecting period. There is always the danger that they might have been overlooked during the first year or two when my collections were not so thoroughly representative as during the last three years. I will therefore venture but a single example: *Oscillatoria princeps,* for which I have a fairly satisfactory five-year record. This alga has been exceedingly abundant at times in one of the ponds from which I have collections at short intervals. These periods of maximum development have occurred without seeming reference to season—aside from absence during the winter.

The diagrams for the several classes of periodicity show their own relative abundance during the different months of the year. The classes, however, do not represent equal parts of the algal vegetation of this region. In Fig. 7 I have attempted to show the relative importance of these several classes. For reasons already stated the Irregulars are not included. One reason why the group of Spring Annuals is of such great importance is that the variety of habitats at this season is vastly greater than at any other period of the year. Habitat diversity and algal variety both have their minimum during late July and August. Fig. 7 also indicates the approximate composition of the algal flora at any time of the year. Thus in October the Perennials and Autumn Annuals constitute the bulk of the forms, with some remnants of the Summer Annuals, some Ephemerals, and some early stages of the Winter Annuals.

With regard to periodicity in general it must not be forgotten, that the classes observed in one locality do not necessarily occur in

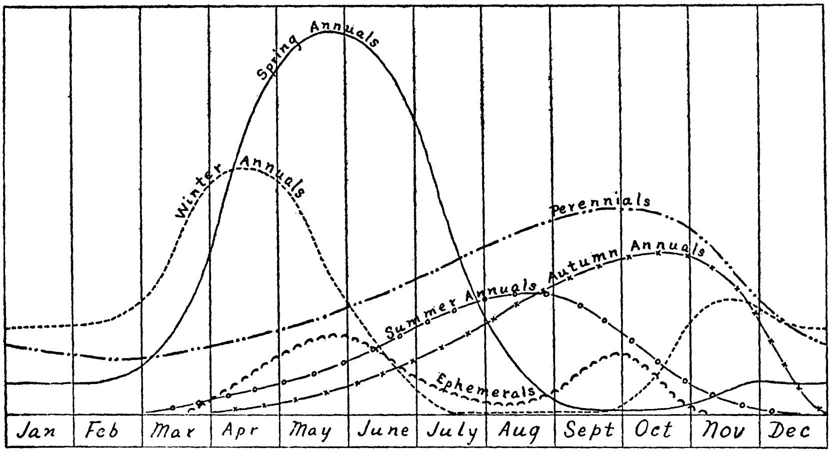


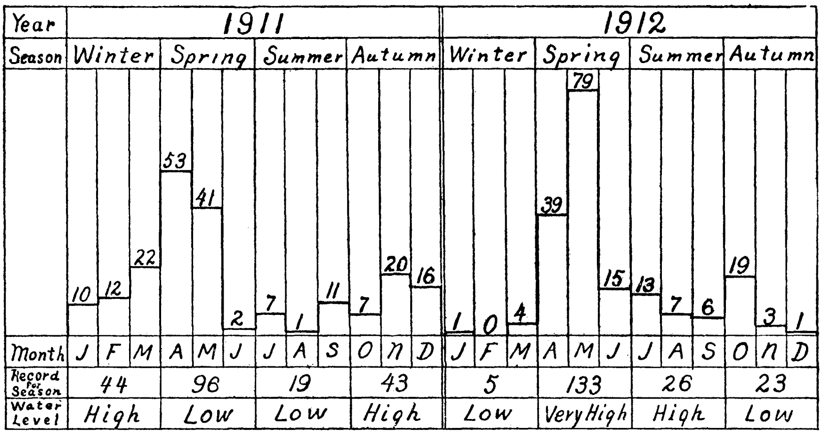
Fig. 7. Estimated relative importance of the several types of algal periodicity, and the composition of the algal flora at any time of the year. This leaves out of account the irregulars.

all others. Indeed, I have good reason to believe that farther north the number of classes is reduced and that two or more may become merged into one. Judging by the publications of Fritsch, in England many of the forms which occur here as winter annuals attain their maximum development there in the summer. Hence we may expect to find considerable local variations in the floristic composition of the periodicity classes.

There is a notion prevalent in the text books and laboratories that algae produce sex organs more abundantly during the low water stages. This is sometimes expressed by saying that we may look for sexually reproductive material when the water begins to concentrate, or "when the conditions become hard enough," whatever that may mean. Or it is said that they remain in a vegetative condition so long as the waters are high. That the opposite of this statement is true was strongly indicated by an examination of my records at the end of my first two years of collecting. In the three years that have since ensued I have watched this particular point with much care, and there can be no question that in this region at least (1) the greatest number of species fruit sexually, (2) a particular species fruits most abundantly, and (3) when a species produces more than one kind of spore, the greatest variety of spores occur during periods of high water. The spring of 1912 was a period of heavy rainfall. The remnants of old prairie ponds along the railroad rights-of-way contained fruiting algae in quantity and variety beyond anything seen during the preceding four years. The high water-level was maintained until after the spores were mature. On examining the corresponding collections for the spring of 1911 I find what are probably the vegetative filaments of many of these same forms, but only a few produced spores. Again, the autumn of 1911 was one of exceedingly high water,—the rainfall of September being more than three times normal. Coincidently a number of species which I had before found fruiting only in the spring, developed and fruited before the pools froze. These algae fruited again in the spring in some of the same pools. Whether the filaments developed from the spores of the preceding autumn, or from spring spores which failed to germinate in the autumn it is impossible to say. But the fact of importance is that the continued high water of the autumn of 1911 was attended by increased fruiting of algae.

The origin of the prevailing notion that algae fruit during low water stages may be connected with the fact that such a large number of algae fruit in late spring when the rainfall is decreasing and the water levels are lowering. This is a coincidence of the lowering water level with the time of fruiting and there is no causal relation between the two. If the weather conditions are such that the water level does not fall at this time of year, but remains constant or rises the fruiting will not only take place but its amount will be increased.

Fig. 8 shows the number of species known to have fruited either sexually or asexually during each month for the years 1911 and 1912. The years are also divided into seasons and the total number of monthly records per season is indicated in the second line from the bottom. In the last line is given the water level, as shown by Weather Bureau records of rainfall, and my own notes. It should further be noted that the seasons during these two years are exactly opposite in so far as rainfall and water levels are concerned. Leaving out of account the temperature conditions which at most are of secondary importance, we have here a basis for direct com-



Year	1911												1912											
Season	Winter			Spring			Summer			Autumn			Winter			Spring			Summer			Autumn		
	10	12	22	53	41	2	7	1	11	7	20	16	1	0	4	39	79	15	13	7	6	19	3	1
Month	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
Record for Season	44			96			19			43			5			133			26			23		
Water Level	High			Low			Low			High			Low			Very High			High			Low		

Fig. 8. Number of monthly fruiting records (both sexual and asexual) grouped by seasons and compared with the water level. It will be noted that for each of the seasons the conditions were opposite in these two years. Note correlation between high water level and increased fruiting.

parison of wet and dry seasons. The close correlation between high water level and increased fruiting is too obvious to need further comment. The only record which shows a marked temperature influence is the one for the winter of 1912. There was not the usual thaw in January and February, which would bring this number nearer the winter mean.

Another notion prevails that sexual reproduction is confined to the time of maximum vegetative development. While it is probably true of a majority of algae, I wish to call attention to the fact that there are many exceptions. When a more detailed report of these collections can be made, there is reason to believe a list of considerable length will show that many algae may reproduce sexually at any or all stages of their vegetative cycle. In other words vegetative development may follow sexual reproduction or may go along with it, as well as precede it.

The failure of algae to fruit in streams has been mentioned by numerous authors. Klebs and Oltmanns speak of the Vaucherias, and Fritsch speaks of the Spirogyras. For eastern Illinois I can record the fact that all the species of *Vaucheria, Spirogyra* and *Oedogonium* known to grow in our streams have been collected at one time or another in fruit. I do not, however, doubt the accuracy of the European observations. Our streams possibly are more sluggish and perhaps there is a chemical difference of importance. The flowing water is generally supposed to retard fruiting by furnishing improved vegetative conditions. Hence we should expect a retarding effect on fruiting which would show clearly in the relative time of fruiting in ponds and streams. On going over the records for species which have been collected in fruit in both situations I find that the stream record is likely to be simultaneous with, or precede, or follow the pond record. As far as I have studied the records there is no evidence of a retarding effect of running water. There is abundant evidence to show that the number of possible combinations of external factors that will produce sexual reproduction is very much less than the number that will induce zoöspore production. Zoöspores may be formed at short intervals throughout the life cycle while the sex organs usually develop at a definite time. The formation of non-motile spores in *Pithophora* seemingly occurs under any and all conditions. This represents the one extreme. At the other is *Zygnema pectinatum* which produced aplanospores but once in the five years and then they were common wherever the *Zygnema* was found.

It seemed best to the writer to await the completion of the examination of the collections before attempting to discuss the literature and the details connected with this problem of periodicity. The names of the green algae used in this paper correspond to those found in Collins' "Green Algae of North America."

Eastern Illinois Normal School,
Charleston, Ill.